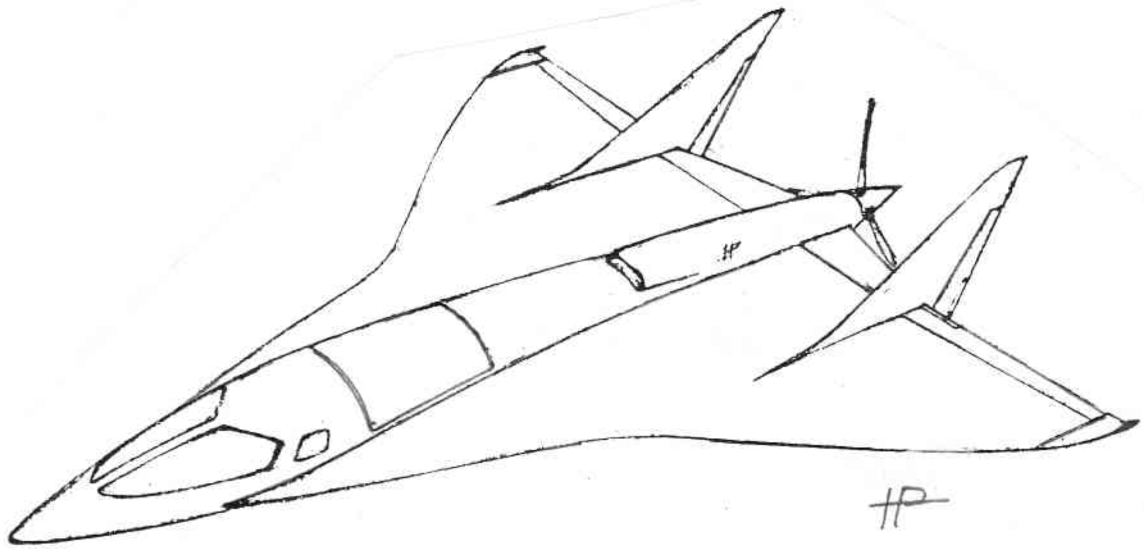
# TWITT NEWSLETTER





TWITT
(The Wing Is The Thing)
PO Box 20430
El Cajon, CA 92021
USA

The numbers in the upper right corner of your label indicate the last issue of your current subscription, e.g. 8809 means this is your last issue.

NEXT TWITT MEETING: Saturday, 17 September 1988, beginning at 1330 hours. As always, the location is Hangar A-4, Gillespie Field, El Cajon, California, in the first row of hangars on Joe Crosson Drive.

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# MINUTES OF TWITT MEETING, 20 AUGUST 1988

Bob Fronius called the meeting to order and announced that he had had some hats made up with TWITT's logotype and that he could get more if there were any interest. The monthly raffle is now a regular item in the agenda; this month's prize was an extension cord. On this day in 1975, the Viking lander made a soft touchdown on the surface of Mars. There is a pile of aviation magazines in the hangar, free for the taking; this is also to be a regular feature of the meetings. At Bob's request a guest, Roger McGee, introduced himself. He is a member of EAA Chapter 14 with a background in Naval aviation and wind tunnel work. Al Faulkner, our first speaker, then arose. He built his first flying wing model glider, a Frank Zaic design, from a kit in 1946 and liked it so much that he built the ship again much more recently from plans alone. As of two years ago, he began competing in the flying wing model competition now sponsored by *Model Builder* magazine, taking third place behind Barnaby and Lynne Wainfan [our April 1988 speakers—Ed]. In his second year of competition he took second place, behind Lynne Wainfan. Al also showed a rubber-powered model consisting of his own fuselage and a wing design published in *Aeromodeller.* Al is working on a scale model of an unsuccessful Gotha reconnaissance airplane design of the Thirties for the new f.w. scale event. The next competition is set for the first Sunday in October at Taft. The Wainfans will not be competing this year, depriving Al, who has provided his rubber-powered model with a folding propeller to enhance its glide, of a chance to beat them.

A 15 minute break ensued.

The next speaker was Maurice Brockington, a member of EAA Chapter 14 who had been engaged for some time in developing a practical 2-rotor Wankel engine conversion for homebuilt aircraft. His interest in the type began when he was designing a two-place trainer. He found he needed a powerplant in three versions: one long-TBO "aircraft" version of 160 horsepower, a supercharged version and a 350 horsepower racing version. The two-rotor Mazda 13B rotary engine seemed to fill the bill; at its race rating of some 300 hp, it was one of the longest-lived racing engines. Maurice quickly discovered, however, that there was not a single satisfactory machine to be found among the many advertised aircraft conversions of that engine; some advertised engines turned out to be pure "smokeware." Not having any experience of his own with Wankel engines, Maurice turned to Racing Beat, an Anaheim, California company specializing in building rotaries for racing. The boss at Racing Beat is a pilot and Glasair builder and took a very strong interest in the project, bringing to it not only his knowledge of the engine but also a very clear understanding of what an airplane needs in front of the firewall. At first Maurice specified a cylindrical engine envelope of 16 inches (41 cm) diameter, but later he eased that requirement to 18 inches (46 cm). Maurice also specified that the engine should be set up for long life, not maximum power. The engine that Racing Beat came up with has 1974 vintage endplates with very conservative porting; the intake and exhaust tracts are both tuned. The engine ran three weeks on a dynamometer before being removed for static display at Oshkosh '88; it was back on the dyno when Maurice addressed TWITT, hence unavailable for display. Maurice wanted 160 horsepower at 6500 rpm; the actual result was 200.5 hp at 6500. With a minimal muffler (the engine is very loud!) he expects 190, and with good muffling 180 hp at 6300 rpm. The brake specific fuel consumption runs .499 lb/hp-hr (228 g/hp- hr) at 143 hp at 5000 rpm, .566 (257) at 6500 rpm. Maurice noted that a Wankel can be leaned out more than an ordinary piston engine, and hopes to take advantage of that fact to get better cruise economy than the SFC figures suggest. The weight of the engine on the dynamometer is 247 lbs (112 kg), but this is expected to increase to 350 lbs (158 kg) with the engine equipped with a propeller speed reduction unit based on a standard Mazda bell-housing. The unit is packaged by Lou Ross and uses a flexplate damper to smooth out torque pulses. The apex seals of a 13B engine can be changed by an expert mechanic in a total of 3 1/2 hours, including removal and replacement of the engine itself. *Air Progress* has an article on the engine, which Maurice calls BEC. Maurice plans further ground testing of the engine, followed by extensive flight tests of the complete powerplant, first in an RV-4 and later in a Mooney. He is shooting for an initial TBO of 2500 hours. The second stage of development of the BEC will be a supercharged version to improve altitude performance only (no sea level boost). The third stage is intended to develop 250 hp at a shorter but still reasonable TBO. The fourth stage machine will be an all-out performance engine for aerobatics, racing and airshow work. No engines will be sold until the test program is complete. Maurice is well aware of the bad reputation that Mazda conversions have in the aviation community and wants all the bugs out of his machine before it hits the market. He has designed a four-seater airplane to take advantage of the engine's unique features, notably its small frontal area. The engine is located in the tail cone with an air inlet at the base of the vertical tail and an exhaust and cooling air exit at the tip of the tail. The engine drives a tractor propeller through a long extension shaft. Because there are no inlets forward, the spinner fairs smoothly into the circular- section fuselage. The shoulder-mounted wing joins the fuselage just aft of the passenger compartment. Seating is back-to-back, with a luggage compartment between the two rows of seats. Bob Fronius closed the coherent part of the meeting by reminding TWITTs of the Sailplane Homebuilders Association meet at Tehachapi on Labor Day weekend.

# LETTERS

### Pioneer II–D Model Flies

*Here's a letter from Bill and Bunny ($B^2$) Kuhlman to Bernie Gross, reproduced because it is of general interest:*

Dear Bernie,

We flew our 1/4 scale Pioneer II-D in Richland, WA, over the weekend and thought we'd drop a note to you letting you know of our success.

This was really an "un"contest—a fun fly. In fact, it was advertised as the "1988 National Mid–Columbia RC Soaring Scale Fun Fly and Soaring Social." It took place over three days, the 27th, 28th and 29th. The site was probably one of the best slope soaring sites in thee United States, a hill with a face of about 40°, a height of several hundred feet and a length of over a mile. it rained Saturday, but Friday and Sunday were great days for flying the ridge lift, with a wind speed of about 25 mph across the lip of the ridge both of those days. The air was fairly turbulent against the hill, but even 50 feet out the air was very smooth with tremendous lift at all times—when the wind slowed down at all it was because of the large amount of air backfilling a thermal that was going through. Visibility from this site is 30 miles to the horizon, and three major thermal streets were visible at all times on Friday. The wind blew steady all day Sunday.

Sixty plus fliers had entered over 100 sailplane and "power scale" (F–16, P–51, F–111, Mirage, "Dago Red," etc.) models. Most of the sailplanes were constructed from kits produced in Germany—fuselage of fiberglass, wings of foam with a covering of balsa, obechi, plywood; ASKs, a Twin Acro, DG–400, Sisu, Discus, Schweitzer 1–26, etc. The power scale ships were of foam with a fiberglas and epoxy covering. Erich Eike, of Canada, had a beautiful German primary glider, complete with pilot, and covered with antique white fabric, and a Reiher. The primary and our Pioneer II-D were just about the only rib and fabric structures at the meet, and the only ones to fly.

Our Pioneer II-D was flown in the "blueprint" configuration, without the modifications of John Irwin's N86TX (which will be added as soon as possible). We tried to get acrylic to conform to our canopy mold, but without success, so $13 in materials later we decided to cover the mold in saran wrap and just get the shape in fiberglass and epoxy. Several people with molding experience talked to us at the meet and we'll soon have a clear canopy so that our future instrument panel and pilot show. We had the fiberglass seat done already, and it was a simple matter to wrap the receiver in foam and seat belt it in place with a strip of velcro. On Wednesday we finally had some decent weather here in western WA and we took her out for a test glide at the Little League field. With just a bit more weight in the nose she was flying fast and straight from a hand launch.

In Richland on Friday we were a pretty anxious pair. Wind at 22 to 28 mph, first soaring flight, etc., etc. Since we had built the whole airplane together, Bill's half was forced to follow Bunny's half when she decided to fly it. We straightened out a few minor problems and were ready. Many people had inquired as to whether a "real" Pioneer II-D actually exists, if our model was a kit that we had assembled, and just how scale it really was. We were able to tell them about N86TX and that it was (hopefully) being flown this same weekend, that it certainly was not a kit, that we had three hand-launched glides on her (only the last being a true success), and that it was indeed scale, airfoil and all. Bunny had constructed the rudder single handed and it's a work of art that a lot of people appreciated—the 1/64" plywood gusseting and 1/32" plywood cap strips could be seen through our still clear covering.

Mike Bamberg, a member of the Portland (Oregon) Area Soaring Society was drafted into launching her, in front of an audience of about 100. Probably half felt she wouldn't fly at all, that she would just tumble through the air into the gravel "like all flying wings:" the other half were hoping that we had done everything right and that it would fly at least well enough to land again in one piece. Mike aimed her down at about a 20 degree angle, an effective angle of attack of zero, and pushed her gently into the air. She continued down for a few feet and then rotated into a beautiful climb—a maneuver that was met with a genuine cheer from everyone in the crowd. Mike's a good coach, and he had us exploring the flight envelope with gentle turns, attempted stalls, tight turns with full up elevator and later with crossed controls. We tried the airbrakes, too. She simply dropped her nose and slowed down, maintaining altitude. Mike flew her for a while, of course, and he remarked that she was a very smooth flying machine. He did a couple of big graceful loops and a nice gentle roll, too!

This site has a gentle roll at the top and then a slightly angled grassy area behind that for landing. There is no rotor and just a bit of turbulence during the last few feet before touching down. Use of the airbrakes was not necessary as her flying speed was just a bit faster than the wind velocity over the crest of the hill, and she settled right in with no problem.

The second flight on Friday was relatively anticlimactic following that initial performance, but more and more people came over for a closer look after each of the two flights. Now they asked about fuselage molds, airfoil templates, construction plans, etc., etc. It was amazing.

Our third flight was on Sunday afternoon. Many people had arrived on Saturday and so had not seen the Pioneer fly previously. We were again inundated both before and after our flight.

Our Pioneer flies just like it's full size: turns can be made flat and gentle, or can be very steep and tight; use of up elevator in a banked turn not only makes it tighter but the airplane accelerates noticeably; the nose doesn't drop below the horizon in a stall, it just comes down a bit and the airplane immediately starts flying faster; full up elevator in lift makes for an interesting experience—the nose goes up to about 45° and she lifts straight up, after a while the nose comes down but if you're still holding full back it just rises again and the whole airplane goes straight up again. We climbed over 800 feet in four "steps" this way and stopped only because the thermal we were in got stronger with each step and we were unsure of getting her down if the thermal became even more intense. And a small amount of down elevator gets her flying extremely fast.

There were three flying wings at the meet—our Pioneer II-D, a foam and fiberglas (sort of a) Horten IV of 12 foot span, and a true to scale 14 foot Northrop YB-49, constructed of foam and fiberglass with fences and fins of lite-ply. It used the same airfoil as the original (NACA 6513–019/6513–018) and the same wing twist (4°), but the only controls were elevons, no flaps or drag rudders. The Horten was launched twice and just did not do well at all; a controlled crash and a noncontrolled crash, probably due to a combination of interference and being tail heavy. The YB-49 had an abortive first flight due to being launched straight out. It stalled and fell, suffering minor damage. The launch for the second attempt was just great (three people and the nose down), it rotated just like the Pioneer and was off. It looked to be flying at about scale speed, but there were a couple of really close passes for the cameras that were unbelievably fast. The turns were graceful and wide, and the whole flight could have been scenes from a late Fifties sci-fi flick. This airplane flew just once, but definitely –stole the show."

One thing that impressed us was that the failure of the Horten was nearly disregarded, and the flight of the YB-49 and the three flights of our Pioneer II-D turned a lot of people on to flying wings! They were at first curious, then intrigued and then genuinely interested. We saw a number of people there become converts. In three flights our Pioneer was flown by both of us, Mike Bamburg, Alan Halleck (the builder of the Horten), and Wil Byers (contest director). Wil has extensive slope experience, he lives just a couple miles from this site, but he had never flown a 'wing before! He said "This thing flies like it has a tail! It's really smooth. This is great!" Alan's designed and flown several flying wings for aerobatics and racing, but he commented on how well she flew, also. We're wondering how the flight characteristics will improve once all the of the hinge gaps are sealed. We've got releasable tow hooks mounted under the wings, so our next flights may be off the winch.

At any rate, this was a success story, and we thought you'd appreciate hearing about it from us.

We'll be sending photos as soon as possible!.

$B^2$

### Interested in Harald Buettner's Control Surface Invention

*And a letter by the same prolific couple to Harald Buettner:*

Dear Harald,

Our first priority upon becoming members of TWITT was to send off for all of the back issues. Recently we have been going through these, getting together a table of contents so we can more easily find things.

During our first readings of the early newsletters we somehow missed the description of your mechanism for replacement of conventional control surfaces. This is an exciting innovation!

For some time we have been looking for a means of sealing the hinge gaps on our models so that laminar flow is maintained to the greatest extent. We've tried Mylar gap covers, hinges made directly from covering material, continuous hinges made from concentric tubes, etc. We've also seen a variety of other methods tried, including "figure 8" hinging, and even elastic hinges made from surgical rubber ribbon. None of these methods works well, as there is always some small gap or break in surface smoothness. Our Reynolds numbers range from 50,000 to 300,000, and so any surface irregularity trips the boundary layer and produces turbulent or separated flow. As we are now doing all our work with foam and fiberglass, your method is very exciting for us; we have never read or seen anything like it. In fact we have already started to make a mock-up of the system for model use, using an Eppler 214 section of six inch chord. We feel that if we can succeed on this small scale then larger chords should not be a problem.

We are absolutely sure that your system will be of great benefit when used in high performance model aircraft, particularly sailplanes, and we would like to see articles in the model press describing the system and its construction. The TWITT newsletter mentioned nothing about patent, copyright, etc., but we do not wish to infringe on your rights in that regard. We would like to promote the mechanism for use in model aircraft, but felt we should contact you for any necessary permissions before starting.

As it has been nearly two years since the TWITT meeting in which you presented your mock-up, we are also eager to know if there have been any improvements to the system since then. Also, if you have any recommendations for modifications for model use.

As one would expect, we are eager to hear from you!

*$B^2$*

*[Editor's Note: Promoting long runs of laminar flow on low Reynolds Number models is not a good idea. The reason is that, below a critical RN of about 500,000, laminar flow does not smoothly change to turbulent flow and go its merry way. Instead, it simply separates after encountering an adverse pressure gradient. Even at higher Reynolds Numbers, there is a brief run of laminar separation before turbulent reattachment occurs. Anyway, the surface flaws that the Kuhlmans are laboring to eliminate are probably saving the model from having a vicious stall! This fact isn't generally known to amateur builders. At Oshkosh '82 I saw proudly displayed an all-metal ultralight which used a NACA 65-series airfoil section, already a vicious stall- monger at full scale RN. Fortunately, the machine had enough dimples, wrinkles and other sources of waviness in its light-gage skin to guarantee early transition. Unfortunately, the max. lift coefficient of the airfoil in fully turbulent ("tripped") flow is very poor, not a good feature on an ultralight...]*

*Harald Buettner responds:*

Dear $B^2$,

I'm terribly sorry that I wasn't able to answer you earlier, but first I was gone for three weeks (Oshkosh), and afterwards work just buried me.

Yes, you are welcome to use my variable camber system in your model airplanes. If you are going to publish anything on it, just give proper credit to my name.

I don't have any improvements on paper yet, but I'm going to use the system in my flying wing design, first in the 1/4 scale model, which I'm working on right now, and in the farther future on the full size one. The main plug for the model molds is existing already.

Please let me know when you come up with some new ideas on the system.

*Harald*

### Need Eppler Airfoil Section Info

*More from the Kuhlmans, this time directed at Yours Truly:*

Dear Marc,

We attended a meeting of the Flight Research Institute on the 24th of May; their featured speaker was Ilan Kroo of Stanford University. Ilan's expertise is in unconventional aircraft designs, and in addition to teaching at Stanford, he's acted as consultant to NASA as well as Boeing and other aerospace firms.

As you know, our interest area is model aircraft, and we were quite eager to learn something new that could be applied to our endeavors. Unfortunately, the topic of flying wings and other tailless designs was at the end of the schedule. Ilan ran short of time, etc., etc., and so the discussion of this topic was cut very short and there was no time for audience questions.

We felt that the topics that Ilan presented would be of interest to other TWITT members; enclosed you'll find a condensation of Ilan's talk. Please feel free to include any/all of it in the newsletter. There were numerous graphs and charts in slide form which were used for illustration purposes, and we wish that we could somehow have managed prints of some of those.

We have no idea if Ilan ever makes it down to the San Diego area, but thought might be given to inviting him to speak at a TWITT meeting in the future. From what we've readd in the newletter, you folks don't have the time constraints on your meeting place. FRI uses the facilities of the

Museum of Flight, and so we must adhere to their schedules.

Last weekend was spent in Richland, Washington, attending a modeling event—a scale slope soaring event. We took our 1/4 scale Pioneer II-D and it flew extremely well. Also there was a semi-scale Horten IV which failed to do anything but tumble (bad CG location and interference) and a magnificent 14 foot span model of the Northrop YB-49 which flew VERY realistically. We took pictures, and a fellow in California is in the process of producing a video of the entire three day affair. We've written a letter to Bernie Gross describing all this in much more detail and we're sure that he's already shared it with you.

The newsletter always makes for fascinating reading, and we look forward to each issue.

*$B^2$*

P.S. Could you direct us toward a source of coordinates for the Eppler 630 series of airfoils (these were the sections used on the Schwalbe II, Issue #1)?

### Sick of Expensive Airplanes and Hot Air

*Dave Laney of Sacramento, California writes:*

Dear Bob,

Thank you for sending out your newsletter (#23) so promptly. I really enjoyed looking through it.

Please find enclosed a check for $ 17.50 for your last 22 back issues—if a dollar for postage isn't enough please let me know...

I am sending for Dr. Lippisch's book which was translated by Gertrude Lippisch. The book is out of print—but I can get a photocopy out of Michigan. I'm hopeful the illustrations are reasonably clear.

I noticed the new T-craft airplane is about $ 40,000 (new tri- gear model). It's really sad that "cheap" aircraft cost so much. As I indicated in my first letter, I've got an hour or two now and have seen a number of aircraft come and go that were supposed to put us into the air at affordable prices. There are a lot of hard headed people in aviation and are probably the root cause of so little progress in so many areas (I was with the ICAO list of experts for a few years and find it went clear to the top). Big Ego and hot air really abound and it's shooting us in the foot. So many ideas, designs and talents are not utilized—or dismissed. For example, while in New Guinea I found a KI-61 fighter and a man in Wewak that had a 61 engine (Kawasaki copy of the Germany DB) that he'd give me for the EAA. I wrote them twice, but they never believed I'd found one—or had an engine to donate—too much hot air over the ears. I know a state-of-the-art aircraft can be put out—and at a reasonable price—and yes, your group has a lot of talent unused and waiting. I really hope you will organize and look ahead into the flying wing for people to build or buy build and fly safely. In any case I hope you will somehow put some wings in the sky in quantity.

Thanks,

*Dave*

### Mitchell U-2 Problems
### Fauvel AV-222

*Edward A. Gabriel of Blue Springs, Missouri writes:*

Dear Bob,

I am enclosing my check for $15 for the TWITT Newsletter as described in the March '88 Pacific Flyer. Please let me know if back issues are available. I am a member of SHA and just cross checked your above address on the membership list and found a slightly different PO box # as above.

I have been constructing and re-designing the Mitchell U-2 motorglider [readers may want to review Klaus Savier's U-2 mods mentioned in previous issues—Ed]. I have found serious structural deficiencies. There have been several fatal accidents which indicate possible aerodynamic or c.g. problems. I recently had the airfoils analysed by the Eppler computer code. The results indicate a very poor airfoil with flow separation and high drag above approx. Cl = 0.8. Do any of your members have information on a suitable reflexed airfoil with approx. t/c = 19%

and max t/c about 35 to 40% chord, or such an airfoil with t/c 16% or greater that I could scale up to 19%? Does anyone have the coordinates (and/or aero characteristics) of the Wortmann FX- 66H-159, or does anyone know where I might be able to obtain them? Please let me know if there is anyone out there who could help me with information on suitable airfoils or if there are any other U-2 builders in your group with information to share.

I am an aeronautical engineer with a long-standing interest in flying wing and motor sailplane design, member of SSA, SHA, EAA (35 years) and AIAA. In the late 70's I became interested in building Charles Fauvel's AV-222 2-place flying wing motor sailplane. I made a proposal to him (to which he agreed) to redesign it with simplified construction for the American amateur sailplane builders. Fauvel died in Sept '79 and the project began to look like it would be too much for one person working alone in very limited spare time. I worked on a translation of the plans and on some of his technical papers. I have a nice collection of many of his papers and greatly respect his work.

A sketch of my proposed modified U-2 and the current airfoils is enclosed. Presently, I am doing some structural tests of the spar shear web at the University of Kansas. I believe the 1 mm shear web with central vent holes to be structurally inadequate. The latest problem I have discovered is the poor airfoil aero characteristics.

A note about my background. Employed by FAA in aircraft certification for the past 12 years. Previously employed by ICAO (3 years) and Boeing Vertol for 10 years. B.S. an Aero Engineering, Penn State Univ. and M.S. in Air Transport Engineering from Cranfield Institute of Technology, England.

Many thanks.

Sincerely,

*Ed Gabriel*

*[Editor's Note: It seems to me (though I don't have my copy of Eppler and Somers' report as I write this) that the Eppler Code can be used for the "inverse problem," that is designing an airfoil section based on desired pressure distribution. It also seems to me that at 19% thickness, separation will be a problem no matter how clever you are at airfoil design. Your specs for max. thickness location will likely aggravate the problem. The NACA 747 series had low negative $C_{m0}$ (zero to slightly positive at low design lift coefficients, and adjustable in any case), but I've never heard of them used at 19% thickness. Still, if you have only airfoil **analysis** codes available to you, you might try designing an airfoil family based on the method given in Abbott and von Doenhoff's Theory of Airfoil Sections, then running them through the code to see what it has to say. You should also get a copy of Eppler and Somers' report to familiarize yourself with the limitations of their code. About your Fauvel material: TWITT would be very interested in acquiring copies. Perhaps we have material in the library which you need, in which case we might work a trade.]*

## *IS THIS YOUR LAST ISSUE?*

Beginning with Newsletter Number 21, mailing labels have had on them a four-digit code for the year and month of the last newsletter the subscriber will receive under his current subscription. If your label reads "8809," for example, your last Newsletter will be this one. Please check your label now, and take the time to renew if your subscription is nearly expired. While we're at it, let us remind you that all back issues are still available at $ .75 apiece. Subscriptions still cost $ 15.00 per year. Payment must be in US Dollars.

# Wing Drag Due to Twist and Sweep Forward

*The following article originally appeared in Soaring, March–April 1956. It is reprinted here last–part–first to fit it into the available space without retypesetting the entire thing. It begins on the next page and continues below.*

*(Continued from page 12)*

sional stiffness to survive the same airspeeds that the straight or swept back wings could stand.

In summary, this study shows that the swept forward wing offers no advantages, throughout a sailplane's speed range, and has several disadvantages. The straight wing without any twist will offer the least drag but the first few degrees of twist offer so little drag that no sailplane should be without at least 1 or 2 degrees of twist. The drag due to twist increases as approximately the square of the amount of twist so for high performance sailplanes the twist should not exceed about 4 degrees for efficient performance.

**References**

(1) NACA TR 921, Theoretical Symmetric Span Loading at Subsonic Speeds for Wings Having Arbitrary Plan Form, by John De Young and Charles W. Harper, 1948.

(2) NACA TR 824, Summary of Airfoil Data, by Ira A. Abbott, Albert E. von Doenhoff, and Louis S. Stivers, Jr.

SEPTEMBER'S SPEAKER

Bradford W. Powers

This will be Mr. Powers second appearance with TWITT, having given a presentation on the concept of dynamic similitude at the June 1987 meeting. Mr Powers, a former Convair engineer, worked with dynamic models of flying boats, and has written several articles for model magazines. At the September meeting he will be discussing weight and balance as the problems relate to scaling up from models to full size aircraft. He will also be showing a film on the Convair Skate, a jet fighter designed to operate from the water, and discuss some of the design features and their inherent problems.

# WING DRAG DUE TO TWIST AND SWEEP FORWARD

BY RICHARD H. JOHNSON

Since the effects of wing twist and sweep forward are important to the design of modern sailplanes and little aerodynamic information on this subject is available to most designers, it was decided that a generalized study should be made available at this time. There are many who advocate elimination or reduction of aerodynamic twist in sailplane wings and also the incorporation of sweep forward in lieu of wing twist to achieve desirable stall characteristics. The following is written to aid designers in their choice of wing twist and/or wing sweep.

Figure 1 shows the five wing planforms that were used in this study. The aspect ratios used were 6, 14, and 22.9. To answer questions about swept forward planforms the aspect ratio 14 wing was studied with sweep angles of 0°, −10°, and −20°. Three different airfoil sections were used with the three aspect ratios. The drag polars for these airfoils are shown in Figure 2. All three airfoils shown are considered by the author to be suitable sailplane airfoils for wings of their respective aspect ratios. For structural reasons the higher aspect ratio wings were assigned the thicker sections. Actually, the choice of airfoil sections had little effect on the results of this study and any airfoil section could have been used with similar results.

The induced drag was calculated for each of the straight wings with no twist and also for these same wings with finite values of twist. These calculations were made for wing lift coefficients between zero and 1.4 by the method described in reference (1). All wing twists considered in this study are linear, that is the wing is twisted so that the leading and trailing edges are straight lines. These results are shown in Figures 3 through 5 as the family of three induced drag curves on each figure. Induced drag is that drag resulting from the formation of lift and its magnitude depends on the distribution of downwash across the span. With the untwisted wings at their angles of attack for zero lift there is no lift anywhere along the span and therefore no induced drag exists. However, for the twisted wings at their respective angles of attack for zero lift the inboard portion of the wings is producing positive lift and the outboard portion is producing negative lift, and although the net result is zero, there still results an induced drag due to the formation of this lift.

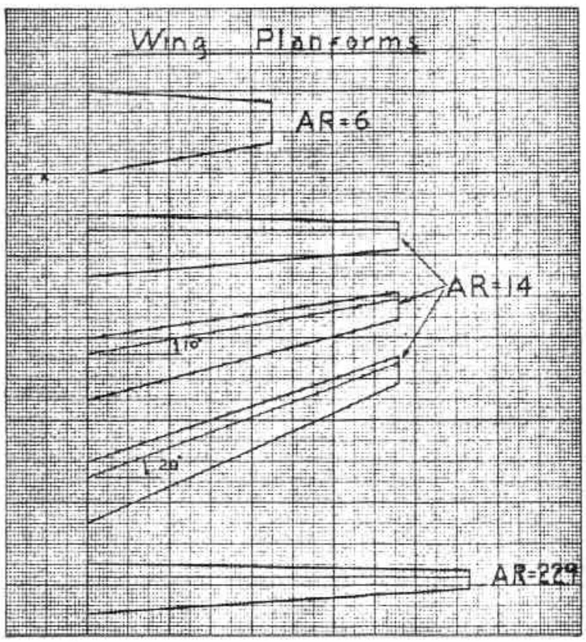



FIG. 1
Wing Planforms Used In Study

Figure 6 shows the induced drag of the aspect ratio 14 wing with no twist but having sweep forward angles of 0°, 10°, and 20°. The sweep angles are measured between the lateral axis and the line joining the quarter chord points of the airfoil sections. This figure shows that all of these wings produce no induced drag at zero wing lift coefficients but at finite lift coefficients the induced drag of the swept wings is higher than that of the straight wing.

In Figure 7 is shown the increment of induced drag that the twist or sweep added to the drag of the straight untwisted wings. Note that the increment of induced drag that is added by the twisted wings is essentially constant at all lift coefficients and is little affected by changes in aspect ratio. Also the magnitude of this increment of induced drag increases approximately as the square of the twist angle.

The increment of induced drag that the sweep forward added to the aspect ratio 14 wing appears to be proportional to the sweep angle, and for a given sweep angle, increases approximately as the square of the lift coefficient.

The drag of a complete wing is made up of the sum of the induced and profile drags. Therefore to look at the total drag of these wings it is necessary to add the profile drag of whichever wing section one wishes to use to the previously discussed induced drag of Figures 3 through 6. As mentioned before the sections used in this analysis and their profile drag polars are shown in Figure 2. Due to the span lift distributions some sections of the wing will operate at higher lift coefficients than the wing lift coefficient and other sections along the span will operate at lower lift coefficients. The total lift of a wing is the summation of the lift along the entire span and likewise the total profile drag of a wing is the summation of the section profile drags which correspond to these section lift coefficients.

The profile drag was calculated for each of the wings for wing lift coefficients between zero and 1.4. Shown in Figures 3 through 6 are these profile drags added to the previously discussed induced drags. It is seen that these induced plus profile drag curves are very nearly the sum of the profile drag curves of Figure 2 and induced drag curves except that at the larger twist angles the definiteness of the low drag "bucket" of the low drag airfoils, used on the aspect ratio 14 and 22.9 wings, vanishes at the higher twist angles.

Figure 8 shows the increment of total drag (induced plus profile drags) that is caused by the twist in each of the wings studied. Except for some variation caused by the low drag "bucket" type drag polars used on the aspect ratio 14 and 22.9 wings, the increment of drag due to twist is almost identical to the increment of induced drag caused by the twist. Similar results would be found for the swept wings also. A plot of the induced drag due to twist versus wing twist angle is shown in Figure 9. This figure shows that the drag added by twisting the wing is very small for twist angles of less than 4 degrees. A small speck of dirt or insect on the wing leading edge could cause as much drag as 3 degrees of twist.

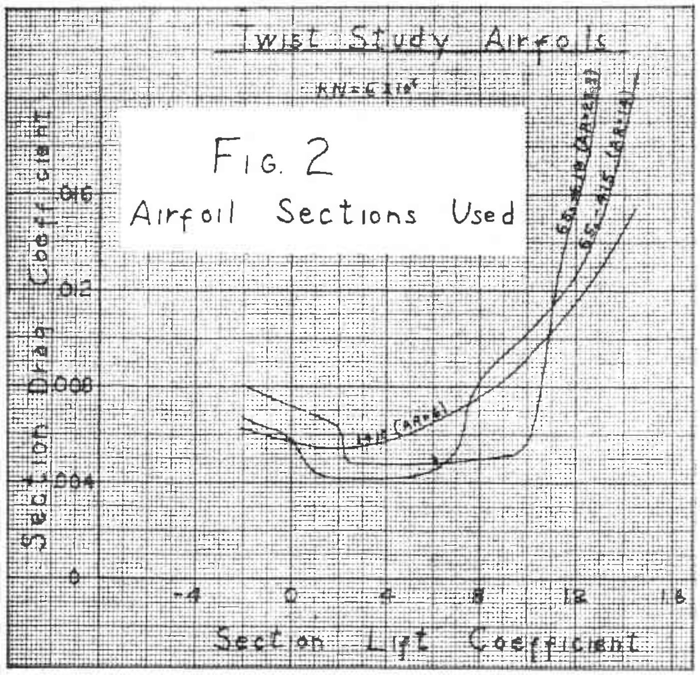



Fig. 2

Airfoil Sections Used

Quite naturally a designer does not wish to increase the drag of his sailplane even by small amounts unless there is something to be gained. That which can be gained by the sacrifice of this drag are the satisfactory stalling characteristics obtained by twisting the wing (washout) or sweeping it forward. Let me emphasize that satisfactory stalling characteristics are quite essential even for the highest performance sailplanes and if they are not provided a considerable penalty will result in the sailplane's performance while thermal or cloud flying.

Now that we have found how much drag is caused by wing twist and sweep forward, it is time to determine just how much twist or sweep is necessary for satisfactory stalling characteristics. For this part of the study the span lift distributions are shown in Figure 10 for the aspect ratio 14 wing for the twist and sweep angles shown in Figures 3 and 6. These span lift distributions show the section lift coefficients which our aspect ratio 14 wing would have while flying near their stalling speeds.

When a wing begins to stall, it does so first at the portion of the wing at which the lifting ability of the wing section is first exceeded. If a wing uses the same airfoil section along its entire span, such as has been used in this study, then its lifting ability is affected only by Reynold's number. In general the lower Reynold's numbers, associated with the shorter chords toward the tip of a tapered wing, provides less lifting ability toward the tip. Reference (2) shows that for our $65_2$-415 airfoil, used with the aspect ratio 14 wings in this study, the maximum lift coefficient available at a Reynold's number of 6 million is 1.61 while at 3 million it is only 1.48. Since the taper ratio used on our

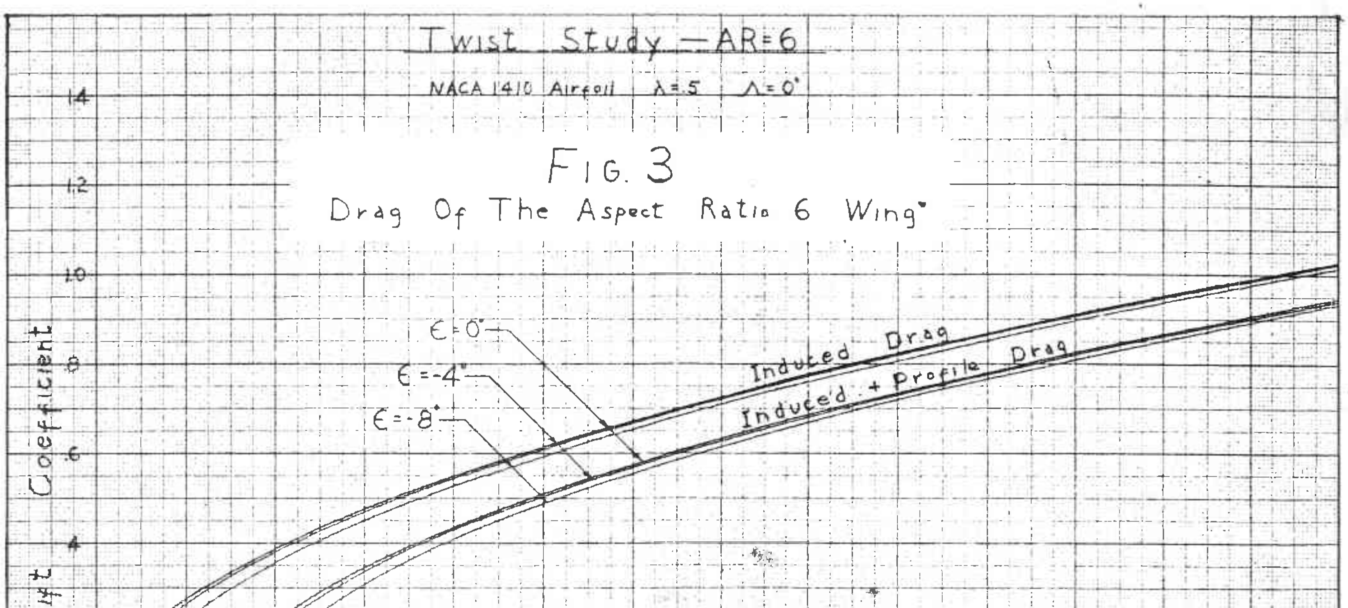
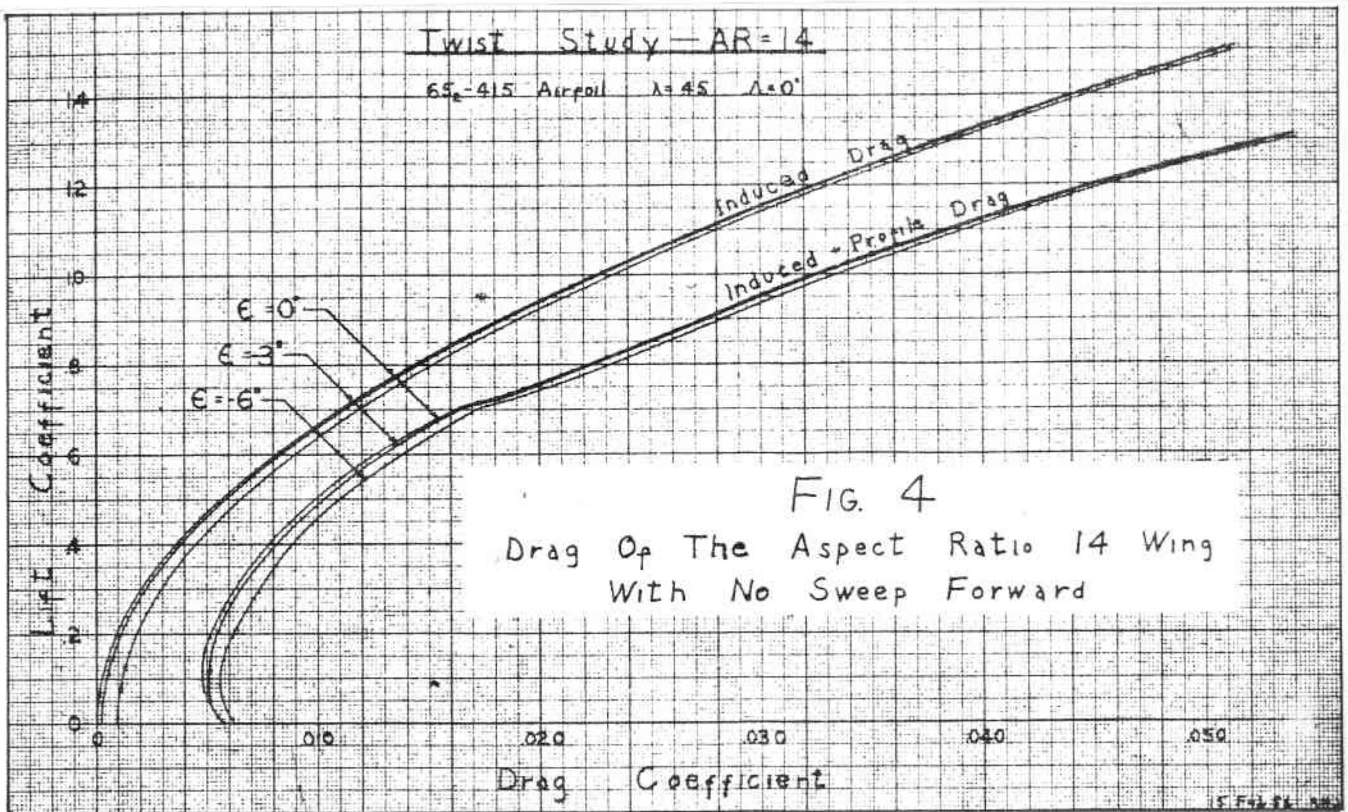


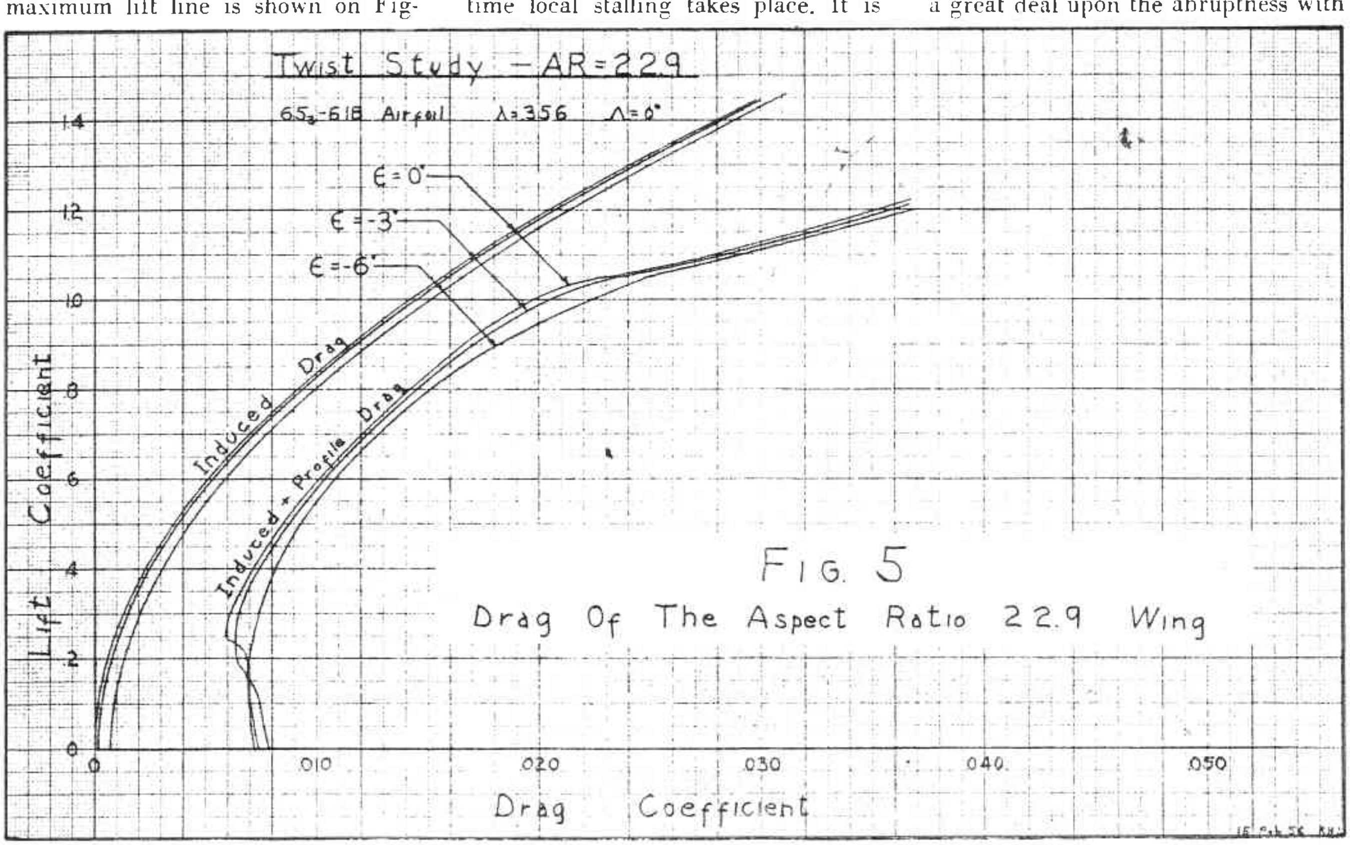

Fig. 3

Drag Of The Aspect Ratio 6 Wing




aspect ratio 15 wing is .45, the Reynold's number at the tip is approximately half that at the root.

Using this change in maximum lift coefficient but displacing the curve downward to correspond to lower Reynold's numbers, the section maximum lift line is shown on Figure 10 as a dashed line. The solid lines show the section lift that exists along the wing semi-span when the total wing lift coefficient is 1.4. At higher wing lift coefficients the solid lines move up until they meet the section maximum lift line, at which time local stalling takes place. It is necessary for the initial stall to occur far enough inboard that serious rolling moments and loss of lateral control will not occur. Just how far out toward the tip and how much of the wing can be permitted to stall and still be satisfactory stallwise depends a great deal upon the abruptness with



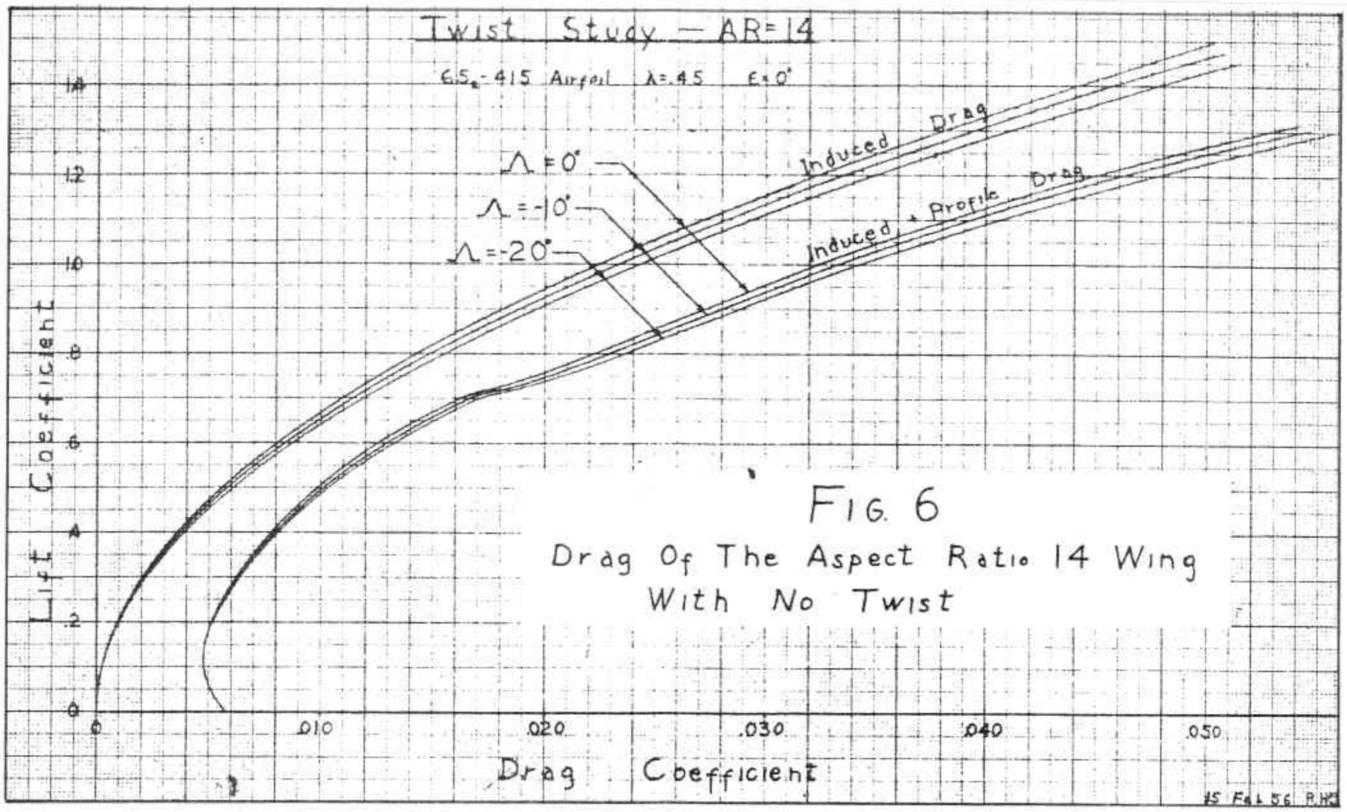



FIG. 6
Drag Of The Aspect Ratio 14 Wing With No Twist

which the airfoil section used loses its lift. Reference (2) shows that our $65_2$ - 415 airfoil has medium to good section stalling characteristics.

Even with good section stalling characteristics it can be seen that the untwisted and unswept wing would stall initially at 60% of the semi-span out from the root and there is little doubt that loss of lateral control and poor stalling characteristics would be the result. By twisting the wing 3° Figure 10 shows that the initial stall would occur at 45% of the semi-span and providing that the section stalling characteristics were fairly good. this amount of twist would probably provide satisfactory stalling characteristics for a high performance type of sailplane when flown by experienced pilots. A sailplane with abrupt section stalling characteristics would probably require 4 to 6 degrees of twist, whereas for a trainer this much twist would probably be desirable even with good section stalling characteristics.

As for the sweep forward necessary to obtain similar satisfactory stalling characteristics, Figure 10 shows that the wing with 10° of sweep forward would stall initially at 50% of the semi-span out from the root and would not be as satisfactory as the 3° twisted wing. It would take an estimated 12 to 13 degrees of sweep forward to provide stall characteristics equivalent to the 3° twisted wing and approximately 17° of sweep to equal the 6° twisted wing stalling characteristics. If the initial stall occurs near the fuselage with this much sweep forward then an added complication of pitch up might further add to the difficulties.

Now that we have determined what values of twist or sweep are necessary, we are now ready to compare their drag characteristics. For wings with 3 degrees of twist Figure 9 shows the increment of drag due to this amount of twist would be .00022. This is a rather small amount of drag even when it is added to a very clean sailplane. The profile drag coefficient on the R-J-5 sailplane is .0105 and the drag due to 3 degrees of twist would only amount to 2.1% of the profile drag. Incidentally, the R-J-5 does have approximately 3 degrees of twist in its wings and it does possess satisfactory stalling

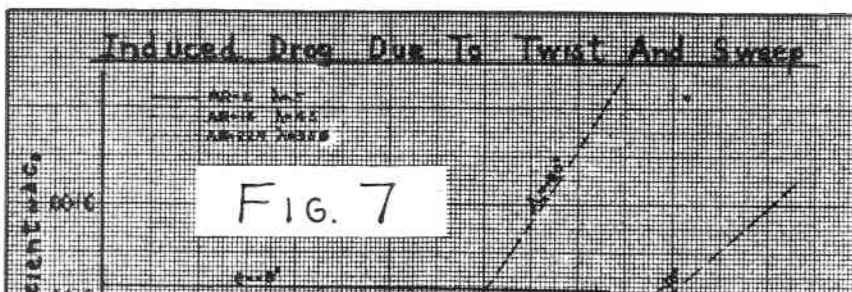
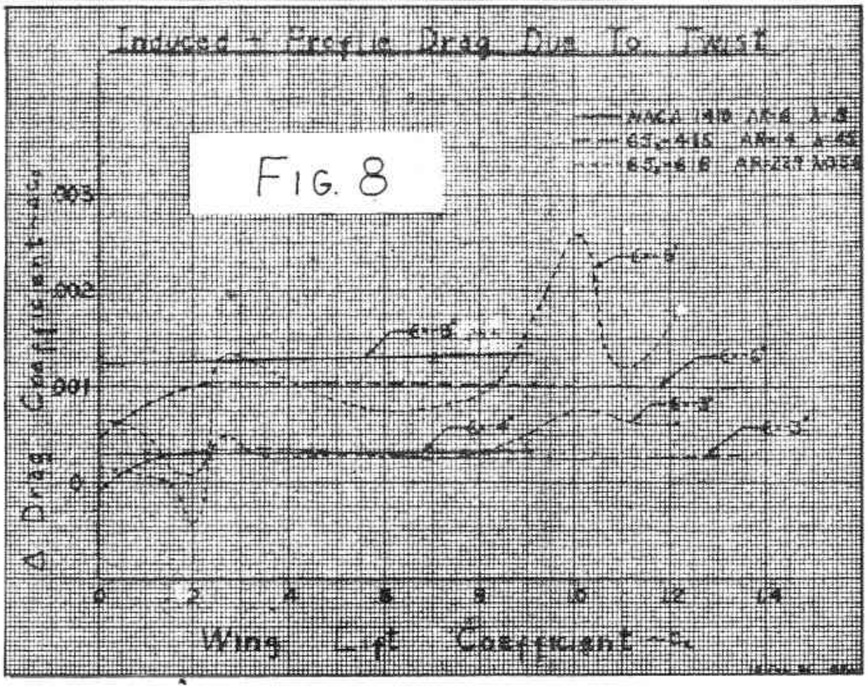


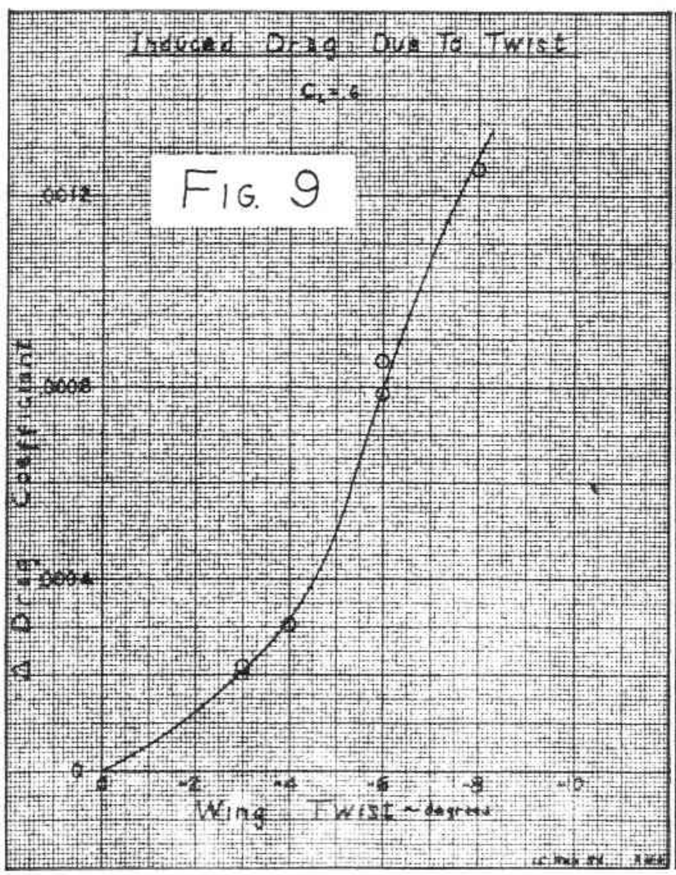

FIG. 7




characteristics for this class of sailplane. This analysis shows that had there been no twist in the R-J-5 wing, its maximum glide ratio could have been 40.4 to one instead of its present 40 to one.

If 12 degrees of sweep forward was used instead of the 3 degrees of twist the increment of drag added is not constant with respect to lift coefficient, but as Figure 7 shows it varies from zero at $C_L$ = 0 and increases as approximately the square of the lift coefficient. For a clean sailplane such as the R-J-5 the best glide ratio occurs at a lift coefficient of .85. Figure 7 shows that at this lift coefficient the increment of drag added by sweeping forward 12 degrees would amount to .00084 or four times as much as the 3 degrees of twist would cost. It is true that at higher speeds the aerodynamic drag of the swept wings decreases and at the high cruise speeds possible on a strong thermal day cross country flight its drag could about equal that of the twisted wing. However, there is another source of drag directly attributable to the swept wing. The sweep forward of the wing is directionally destabilizing and therefore more vertical tail area will be required to provide the same amount of directional stability that the unswept wing would have. To counteract the destabilizing effect of the 12 degrees of sweep forward it would be necessary to increase the vertical tail area by approximately 2% of the wing area and this added area would increase the drag of the swept forward configuration by an additional .00012 at all lift coefficients. This would mean the swept forward wing would have more drag than the twisted wing at lift cofficient above .25. This lift coefficient corresponds to 94 MPH for the R-J-5 sailplane and this speed is about 10 MPH faster than the most efficient cruise for the R-J-5 on a strong thermal day.

Structurally the swept forward wing has another disadvantage in that it is basically unstable in flutter and would require much more tor-



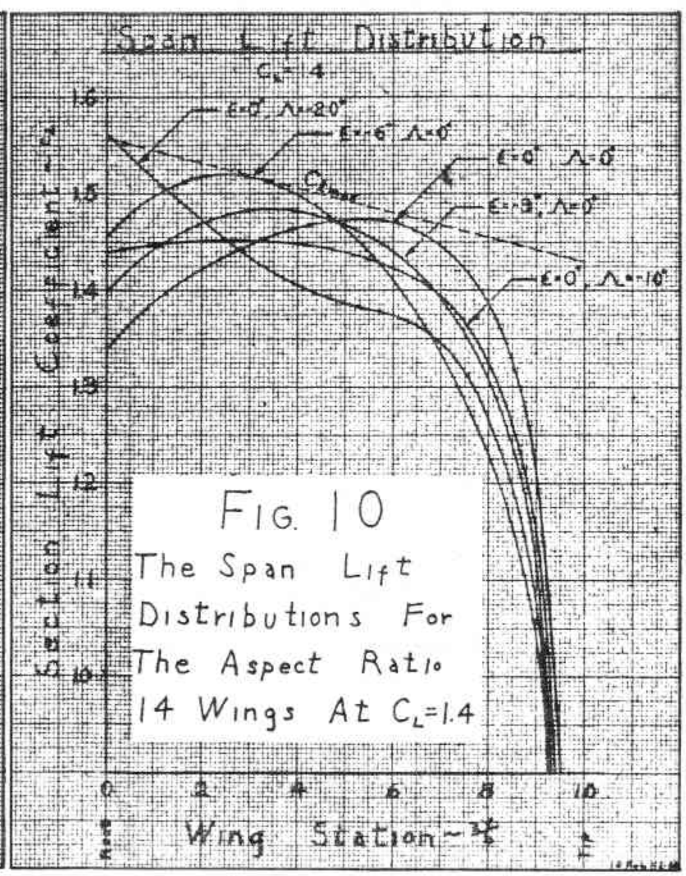




FIG. 10
The Span Lift Distributions For The Aspect Ratio 14 Wings At $C_L$=1.4